AGRICULTURE

Success Story

Continuous Cascade Fermentation System for Chemical Precursors

Low-Energy Continuous System Converts Waste Biomass to Ethanol

Benefits

- Has displaced 0.48 trillion Btu of gasoline through 2000
- Has avoided 38,000 tons of CO_2 emissions from gasoline combustion through 2000
- Increases the fermentation capacity of ethanol plant by a factor of 2 to 6 times

Applications

Converts a variety of materials to ethanol or other chemical precursors with complete fermentation of feedstocks and removal of ethanol into a gas phase as it is produced.

" The Inventions and Innovation grant helped demonstrate this low-energy, continuous process for production of ethanol from biomass substrates."

– Dr. M. Clark Dale
President
Bio-Process Innovation, Inc.

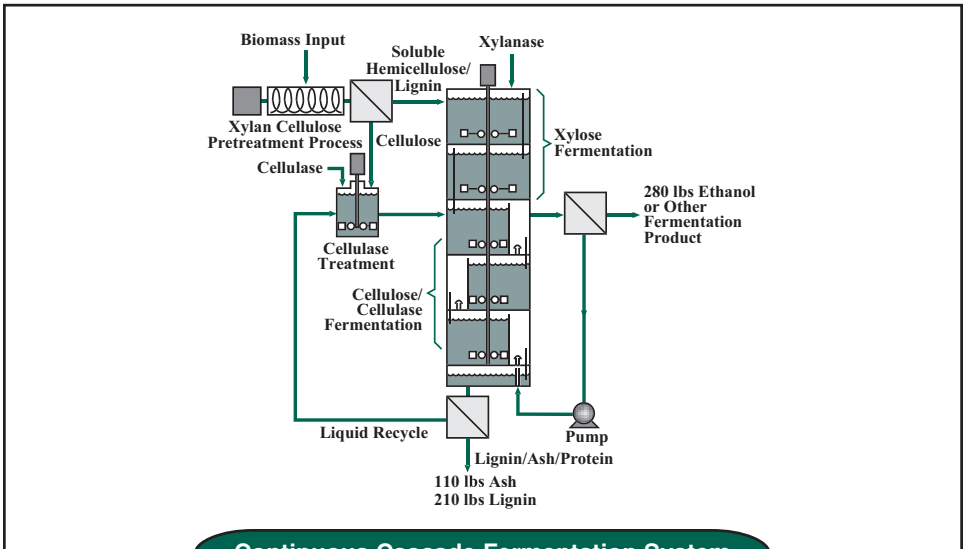
" I think BPI's biomass to ethanol process has a massive international potential. I was thinking of local co-op plants making low price auto fuel for rural areas as well as giving farmers another income, and maybe stop them from burning stubble which would be good for the environment."

– Michael Bond
Australia

Using ethanol in transportation fuel will reduce U.S. petroleum usage. Ethanol can be made from fermenting biomass, although the product requires tax credits to be cost-competitive. The economics of ethanol production are improved when wastes are used as feedstock. Each year the U.S. food processing industry generates over 30 billion pounds of waste starches and sugars. While these wastes are a significant disposal problem for food processors, they represent a large potential feedstock for ethanol producers.

With assistance from the U.S. Department of Energy's Inventions and Innovation Program, Bio-Process Innovation (BPI), Inc. developed and tested a continuous cascade fermentation system for producing ethanol from waste sugars. BPI is currently working towards applying the technology to waste paper, cornstalks, straw, or sawdust.

As shown in the schematic, biomass feed is introduced continuously into the first of three to five stirred reactors placed in series, with the outflow of one reactor flowing into the next reactor. The liquid stream that moves from reactor to reactor is contacted with a stripping gas to remove the ethanol. A low-energy solvent absorption/extractive distillation system extracts ethanol from the stripping gas and recovers the gas for reuse. Separating the ethanol product as it is formed increases the rate of ethanol



Continuous Cascade Fermentation System

production. BPI, Inc. also developed a highly flocculent yeast that further speeds the reaction of sugar to ethanol by maintaining high cell densities while operating continuously. The final effluent from the fifth reactor consists of waste lignin and ash, which are dewatered so the water can be recycled back to the process.

A five-stage, 40,000-gallon unit has been operating at Permeate Refining Company in Hopkinton, Iowa, since June 1996 on waste starches and sugars. The unit produces about 1 million gallons of ethanol per year at a cost of just under $1 per gallon. A small pilot unit operating on cellulosics is currently being tested at BPI, Inc. in West Lafayette, Indiana. A small plant in Spring Green, Wisconsin (Spring Green Ethanol), is now using BPI's technology for converting permeate mother liquor to ethanol. Several companies are currently evaluating BPI technology for whey- and molasses- based ethanol plants to be sited and built in the near future.

Two three-stage permeate mother liquor fermentation units for lactose were operating at Minnesota Clean Fuels (Dundas, Minnesota) and Eco-Products (Plover, Wisconsin). The Minnesota plant opened in December 1996 and the Wisconsin plant opened in 1998. The units processed approximately 2 million gallons of ethanol before both plants shut down in 1999 due to financial difficulties.

Table 1 shows the net energy generation from a gallon of ethanol when using wastes as feedstock and BPI's continuous bioreactors. Therefore, since 1996 producing 6.5 million gallons of ethanol using the continuous cascade bioreactor has displaced about 0.48 trillion Btu of fossil fuels. The carbon dioxide formed during ethanol combustion was balanced by that amount absorbed during the annual growth of plants used to produce ethanol.

Table 1. Estimated Net Energy from Ethanol Using New Process

Component	Btu/Gallon Ethanol
Waste Feedstock Transport	1,000
Ethanol Conversion	8,000 (dry) to 28,500 (wet)
Ethanol Distribution	1,000
Total Energy Used (A)	10,000 to 30,500
Energy Value of Ethanol (B)	84,000
Net Energy Production (B-A)	53,500 – 74,000

Industry of the Future — Agriculture

Agriculture, a target industry for the Industry of the Future initiative, emphasizes partnerships to develop technologies for using plants, crops, and their wastes as starting materials for industrial products. An agriculture industry team has been formed within the Office of Industrial Technologies (OIT) to facilitate agriculture industry/federal government partnerships. This team will leverage resources available to established OIT teams, such as the chemicals and forest products teams, to strengthen the contributions of the agriculture team and to bring new ideas to the service of the agriculture industry.

OIT Agriculture Industry Team Leader: Mark Paster (202) 586-2821.

The Inventions and Innovation Program works with inventors of energy-related technologies to establish technical performance and to conduct early development. Ideas that have significant energy-savings impact and market potential are chosen for financial assistance through a competitive solicitation process. Technical guidance and commercialization support are also extended to successful applicants.

Project Partners

- Inventions and Innovation Program
- DOE Industrial Wastes Program
- Bio-Process Innovations, Inc.
- Permeate Refining Company
- Xylan, Inc.
- The Great Lakes Regional Biomass Energy Program
- Spring Green Ethanol, Inc.

For project information, contact:
Dr. M. Clark Dale
President
Bio-Process Innovation, Inc.
226 North, 500 West
West Lafayette, IN 47906-8505
Phone: (765) 746-2100
Fax: (765) 746-2100
bpidale@concentric.net

Home Page:
www.bio-process.com

For more information about the Inventions and Innovation Program, contact:

Lisa Barnett
Program Manager
Inventions and Innovation Program
U.S. Department of Energy
1000 Independence Avenue SW
Washington, D.C. 20585-0121
Phone: (202) 586-2212
Fax: (202) 586-7114
lisa.barnett@ee.doe.gov

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